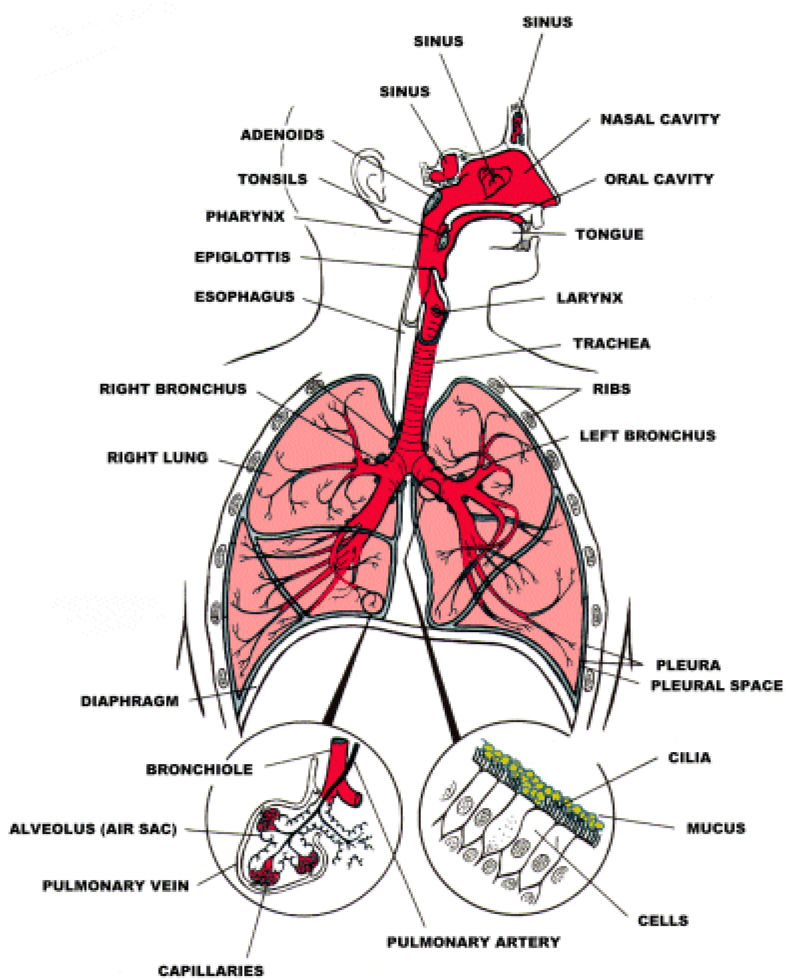
THE RESPIRATORY SYSTEM



BIOLOGY

FOR

GENERAL SECONDARY CERTIFICATE

Unit (I)
Chapter (3)
Respiration in Living Organisms

The concept of respiration
Its importance to living organisms.

Green plants absorb energy from sun light, and change it into chemical energy during photosynthesis. They store the chemical energy in high-energy compounds, the most important of which are carbohydrates, especially glucose. Respiration process comprises the uptake of Oxygen and the release of CO_2. In case of unicellulars, Oxygen diffuses directly into the cell, and CO_2 passes out as a bi-product. In case of multicellulars, the presence of a respiratory system is essential. Uptake of Oxygen and release of CO_2 is called gaseous exchange, which is completely different from cellular respiration.

The cellular respiration:

Cellular respiration is the process by which energy is extracted from bonds of food molecules manufactured by plants or eaten by animals. The released energy is used in generating ATP molecules.

The importance of glucose in cellular respiration:

Carbohydrates, especially glucose is considered as a form of stored energy that can be transferred from one cell to another and from one living organism to another.

The glucose molecule is considered as an excellent example to study the steps of breaking down the food molecules, as it is the molecule commonly used by the majority of living organisms to produce energy more than any molecule of available food.

Role played by ATP (Adenosine tri-phosphate) molecules:

Any energy required by a cell, needs ATP molecules. ATP molecule is considered as the small currency of energy. It can be easily spent and exchanged, it can be considered as the universal currency of energy in the cell.

The structure of ATP molecules:

ATP molecule is built up of 3 subunits:

1. Adenine: Which is a nitrogenous base (has the properties of a base)

2. Ribose: This is a 5-Carbon sugar (a pentose)

3. Three phosphate groups: Those are linked together by two high energy bonds.

During cellular reactions, only one of these bonds usually break down, only one phosphate group is removed by hydrolysis of an ATP molecule, which becomes ADP (Adenosine di-phosphate), and an amount of energy (which is about 7-12 K Cal/mole) is released.

Adenosine tri-phosphate ⟶ Adenosine di-phosphate + A Phosphate group + Energy (7-12 K Cal/mole)

Steps of cellular respiration:

(The complete oxidation of a glucose molecule):

The process of cellular respiration starts with a glucose molecule, and can be summarized in the following equation:

$$C_6H_{12}O_6 \xrightarrow{\text{Respiratory enzymes}} 6\ CO_2 + 6\ H_2O + 38\ ATP$$

Cellular respiration takes place in three major stages:

1. Glycolysis:

That takes place in the non organ part of the cytoplasm (cytosole) of the cell.

2. Krebs cycle

3. Electron transport

Those take place both inside the mitochondria, where respiratory enzymes, water, phosphate groups, co-enzymes, and electron-carrier molecules (cytochromes) exist.

Hydrogen Carriers:

During Glycolysis (break down of glucose), and Krebs cycle, Hydrogen atoms are removed from the Carbon skeleton of the glucose molecule that pass to co-enzymes (NAD^+ and FAD) which act as Hydrogen carriers:

$$NAD^+ + H_2 \xrightarrow{\text{Reduction}} NADH + H^+$$

$$FAD + H_2 \xrightarrow{\text{Reduction}} FADH_2$$

1. Glycolysis:

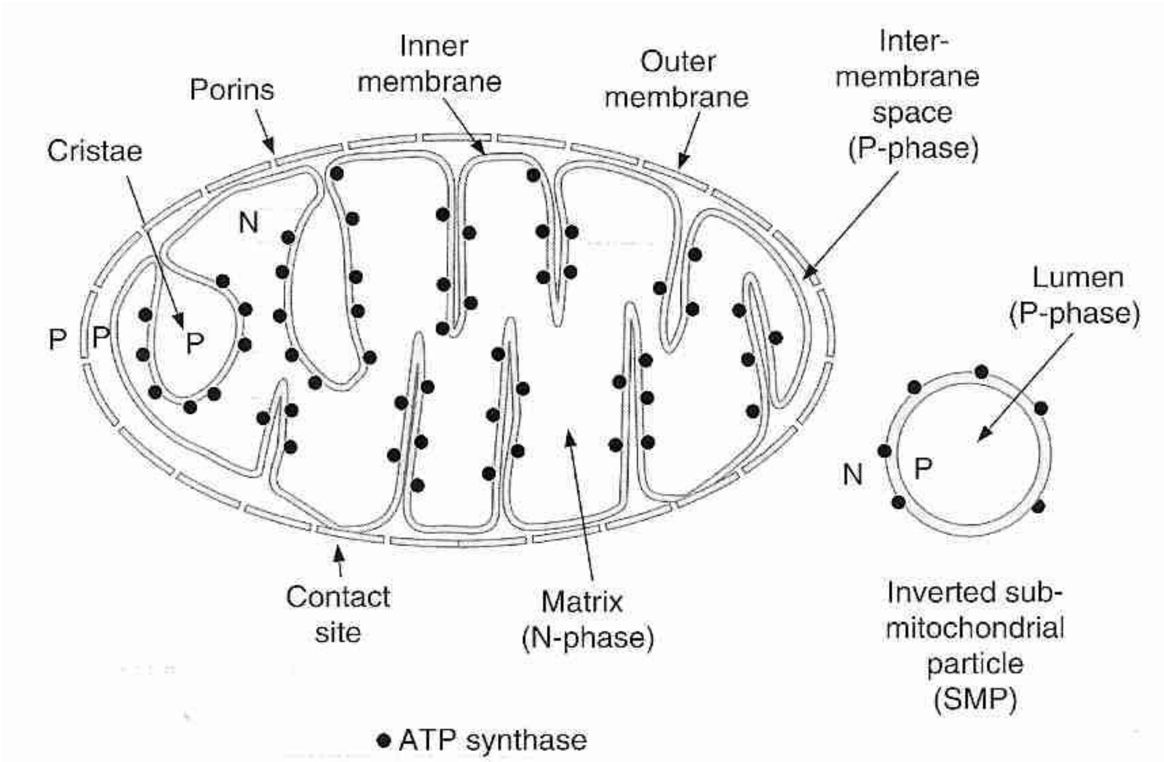
Glycolysis takes place in both aerobic and anaerobic respiration to produce energy. In Glycolysis one molecule of glucose breaks down forming two molecules of pyruvic acid (3-carbon), two molecules of ATP, and two molecules of NADH + H^+ passing through a group of reactions through which glucose is converted into:

1. Glucose 6-phosphate (6-carbon)
2. Fructose 6-phosphate (6-carbon)
3. Fructose 1-6-diphosphate (6-carbon)
4. Two molecules of PGAL (phosphoglyceraldehyde) (3-carbon)
5. Two molecules of pyruvic acid (3-carbon).

So, the oxidation of the glucose molecule into 2 pyruvic acid molecules is accompanied with:

- **The reduction of 2 molecules of NAD^+ into 2 molecules NADH + H^+**
- **The production of 2 molecules of ATP in the cytosole of the cell.**

NAD+ : Nicotine amide adenine di-nucleotide.
FAD : Flaven adenine di-nucleotide.



All these reactions occur in the absence of Oxygen, so they are called anaerobic respiration. The energy resulted is not enough to perform all the vital activities of living organisms. Therefore, in the presence of Oxygen, pyruvic acid molecules pass into the mitochondria to produce more energy. This takes place in two consecutive stages: Krebs cycle, and electron transport.

$$C_6H_{12}O_6 \xrightarrow[\text{Respiratory enzymes}]{\text{Anaerobic respiration}} 2C_3H_6O_3 + 2ATP$$

2. Krebs cycle:

Krebs cycle takes place in two stages:

Stage 1:

Each molecule of the two pyruvic acid molecules (3-carbon) is oxidized in the presence of Co-enzyme-A into acetyl Co-A (2-carbon) that join Krebs cycle. In this reaction:

- Two molecules of NADH + H^+ are produced.

- Two molecules of CO_2 are produced.

$$\underset{\text{(3-carbon)}}{\text{2 Pyruvic acid}} + \text{2 Co-A} \xrightarrow{2NAD^+ \rightarrow 2NADH + H^+} \underset{\text{(2-carbon)}}{\text{2 Acetyl Co-A}} + 2\,CO_2$$

<u>N.B:</u> Acetyl groups from breaking down fat molecules or protein molecules can combine with Co-A to join Krebs cycle.

<u>Stage 2:</u>

Each molecule of Acetyl Co-A joins Krebs cycle where its Co-A splits off to repeat its role. At the same time, Acetyl group (2-carbon) combines with Oxaloacetic acid (4-carbon) to form Citric acid (6-carbon):

Acetyl Co-A (2-carbon) + Oxaloacetic acid (4-carbon) ⟶ Citric acid (6-carbon) + Co-A

Citric acid passes through three intermediate compounds to form Oxaloacetic acid once more. These compounds are:

- **Ketoglutaric acid (5-carbon)**
- **Succinic acid (4-carbon)**
- **Malic acid (4-carbon)**

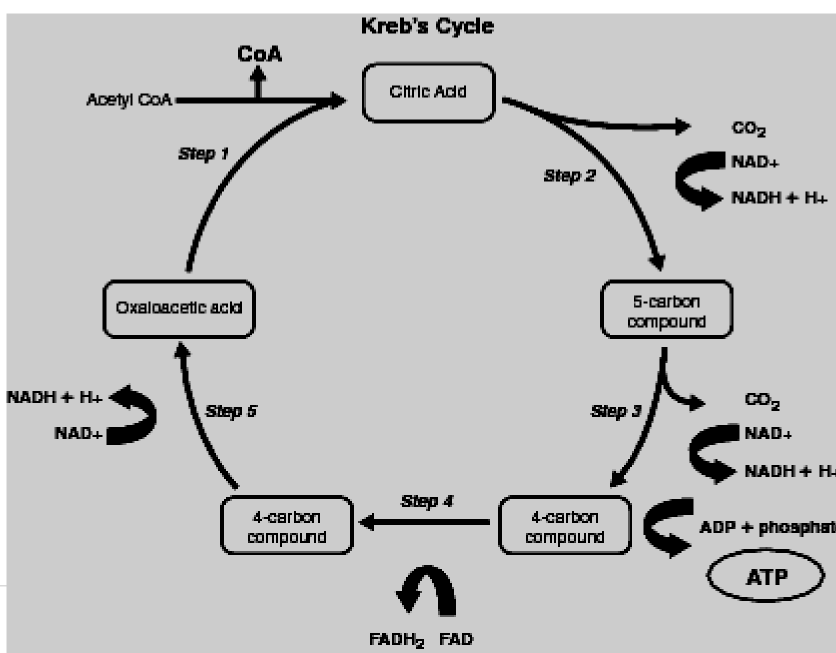
<u>Krebs cycle</u> is also called Citric acid cycle, because Citric acid (6-carbon) is the first compound formed during this cycle due to the combination of Acetyl Co-A (2-carbon) with Oxaloacetic acid (4-carbon) to form Citric acid (6-carbon).

<u>Oxidation during Krebs cycle</u> doesn't need Oxygen, since all electrons and protons are removed from the carbon skeleton during oxidation of carbon atoms and received by NAD+ and FAD that are reduced into NADH + H+ and FADH2

<u>In the pathway of Krebs cycle:</u>

- **2 molecules of CO2 are released.**
- **1 molecule of ATP is produced.**
- **3 molecules of NADH + H+ are produced.**
- **1 molecule of FADH2 are produced.**

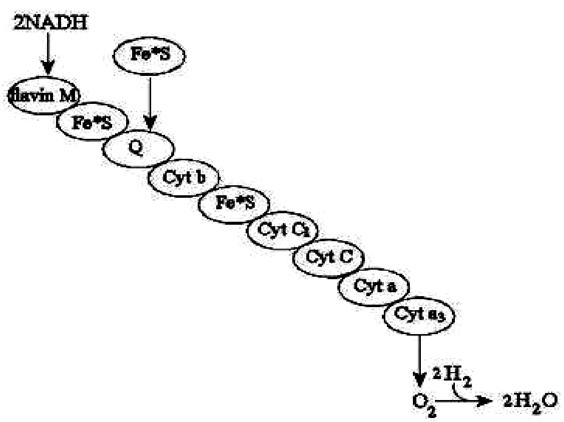
<u>Krebs cycle</u> is repeated twice for each glucose molecule.



3. Electron transport chain:

At the end of Krebs cycle, Hydrogen with high-energy electrons carried by NADH + H^+ and FADH2 are transported by a sequence of Co-enzymes called cytochromes (electron carriers) present at the inner membrane of the mitochondria. These cytochromes carry electrons at different energy levels. These high-energy electrons are passed from one cytochrome to another, and at the same time they descend from higher energy levels to lower ones. During this, energy is released to form ATP from ADP + A phosphate group. This process is called Oxidative phosphorylation:

$$ADP + P + Energy \longrightarrow ATP$$



Oxygen is considered the last receptor of Hydrogen in the electron transport chain, where the two electrons combine with the two protons and one Oxygen atom to form a water molecule. As follows:

$$2e^- + 2H^+ + \frac{1}{2}O_2 \longrightarrow H_2O$$

<u>In the electron transport chain:</u>

Each NADH + H+ molecule releases energy enough to form 3 ATP molecules. While each FADH2 molecule releases energy enough to form 2 ATP.

<u>Accordingly, during aerobic respiration, each molecule of glucose produces 38 ATP molecules, two of which are produced in the cytoplasm of the cell during glycolysis, and 36 ATP molecules are produced inside the mitochondria (the respiratory stage).</u>

Anaerobic respiration:

When Oxygen is missing or in low quantity, living organisms as Bacteria and Fungi respire by anaerobic respiration. Some plant and animal cells may also respire anaerobically when Oxygen is not available. This is also called fermentation, and it doesn't need Oxygen, but it takes place in the presence of some special enzymes.

Anaerobic respiration begins with the same beginning of the aerobic respiration. The Glucose molecule is decomposed into two molecules of pyruvic acid, with the formation of two molecules of NADH + H^+ and a small quantity of energy (2 ATP molecules)

Pyruvic acid is converted according to the type of the cell in which it was formed:

- In case of animal cells, especially muscle fibers, when the muscles exert vigorous efforts or exercises, they consume most of the Oxygen in their cells and tended to convert Pyruvic acid into Lactic acid after its reduction by combining with Hydrogen on NADH + H^+

This is known as Muscular Fatigue. If Oxygen is available, Lactic acid is converted into Pyruvic acid again and then into Acetyl Co-A.

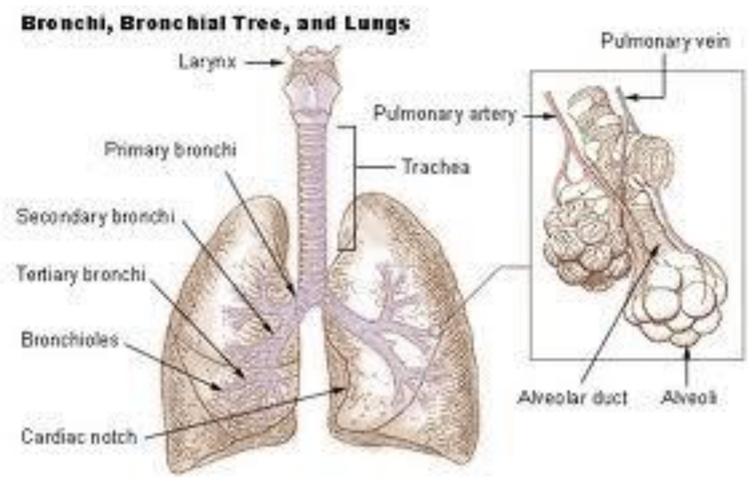
- In case of Bacteria, Pyruvic acid converts into Lactic acid.

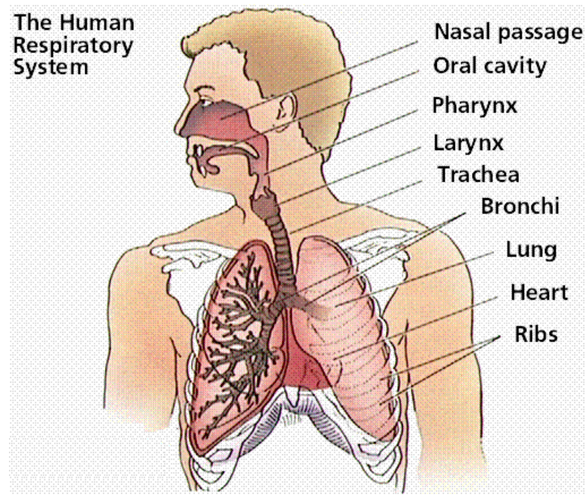
$$C_6H_{12}O_6 \xrightarrow{\text{Acidic Fermentation}} 2C_3H_6O_3 + 2ATP$$

- In case of Yeast fungus, or in some plant cells, Pyruvic acid is reduced into Ethyl alcohol and Carbon dioxide. This process is called Alcoholic Fermentation and is used in the industry of some products.

$$C_6H_{12}O_6 \xrightarrow{\text{Alcoholic Fermentation}} 2C_2H_5OH + 2CO_2 + 2ATP$$

The Respiratory System in Man





1. An air entrance:

Air enters the body through the nose or the mouth. It's preferable for air to enter through the nose because:

a. This passage is warm, as it is lined with numerous blood capillaries.

b. This passage is moist, as it secretes mucous.

c. This passage serves as a filter, as it contains hairs that act as a filter.

2. The Pharynx:

Pharynx is a common passage for both air and food.

3. The Larynx:

Larynx is also known as the voice box.

4. The Trachea:

Air enters the trachea through the larynx. The trachea wall contains a series of cartilage ¾ rings which prevent the trachea wall from collapsing, thus maintaining an open passageway for air.

The inner surface of the trachea is lined with cilia which beat upwards to create air and mucous currents; this impedes the entry of small foreign bodies and moves them to the pharynx, where they may be swallowed. The trachea is divided at its lower end into two bronchi.

5. The two bronchi:

Each bronchus enters a lung, where it divides and sub-divides into progressively smaller and smaller bronchioles. Each bronchiole finally opens into one of the many alveoli (air sacs), of which there are about 600 millions per lung.

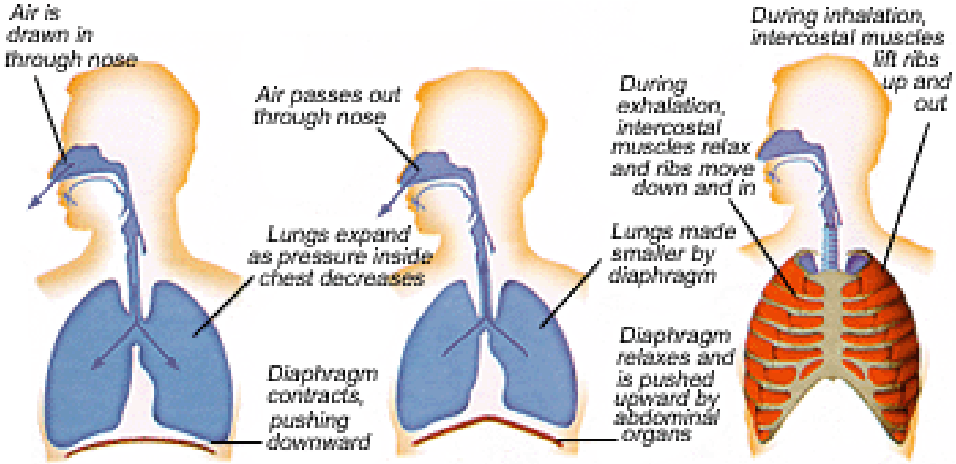
N.B.: 1. The thin alveolar walls are considered the actual respiratory surface, as they are surrounded with a large network of blood capillaries. Blood receives Oxygen from the alveolar air and carries it to the rest of the body. It gives out CO2 to the alveoli in return, so that it may get rid of it.

N.B.: 2. The whole group of alveoli, and bronchioles connected to them, together with the huge network of capillaries, constitute the lung. Each animal, and also Man possesses two lungs, a right lung, and a left lung.

Mechanism of respiration in Man

Mechanism of respiration in Man is the responsibility of:

1. **The diaphragm: The respiratory muscle.**
2. **The intercostals muscles: Two groups of internal and external chest muscles that move the ribs.**

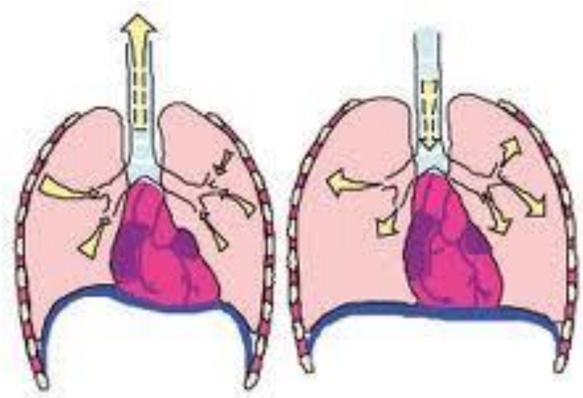


In case of inspiration:

- **The internal muscles between the ribs contract, thus moving them up.**
- **The diaphragm muscle below the lungs contracts.**

- The chest cavity increases.
- The internal pressure of air inside the lungs is reduced.
- The outside air flows from the outside through the nose and downwards through the trachea and finally into the lungs.

In case of expiration:



- The ribs muscles relax.
- The diaphragm relaxes.
- The volume of the chest cavity is reduced.
- The internal pressure increases.
- Air is forced outside the lungs.

N.B.:

1. During each respiratory cycle (inspiration and expiration), the aeration of the lungs does not exceed 10% of its capacity. This ratio varies according to:
a. The state of the individual between rest and exhaustion.
b. The depth of the inspiration.

2. At the end of expiration, a part of air is always left in the lungs to warm the new air coming to the lungs, and prevent the adhesion of the alveoli membranes from the inside.

3. The human lungs are characterized by having a large surface area through which gas exchange occurs.

4. The changes in the rate and depth of respiration are accompanied with similar changes in heart beats. This is regulated by the centre of respiration in the brain.

5. The respiratory system in Man plays an important role in the excretion of water, as the expired air contains water vapor. Man usually loses daily about 500 cm3 of water through his lungs out of the 2500 cm3 of water that he loses daily. This is due to the evaporation of water that moistens the alveoli membranes. This water is necessary for dissolving Oxygen and Carbon dioxide, so that the exchange of gases between the air of the alveoli and the surrounding blood in the capillaries occurs.

Respiration in Plants.

The green plant absorbs light energy from the Sun and transforms it into chemical energy through photosynthesis process to store as high energy complex organic molecules (glucose). Whenever the plant needs energy to carry out one of its vital activities, it releases this energy slowly in a chain of reactions which includes breaking down of carbon bonds of the organic substances. This is the process of respiration in plants. If Oxygen is present, aerobic respiration occurs, but if Oxygen is absent it is called anaerobic respiration.

Gaseous exchange:

1. In most plants:

Each living cell is in direct contact with the external environment and therefore gaseous exchange is easy. Oxygen gas diffuses inside, while Carbon dioxide is released outside the cell.

2. In vascular plants:

That are complicated in structure, Oxygen reaches the cells through various passage ways:

a. Through the stomata of leaves, when they open, air enters to the air chambers and then diffuses through the intercellular spaces spreading to various parts of the plant. Oxygen then diffuses through the cell membranes and dissolves in the water of the cell. Some of the Oxygen is carried to the phloem passage way, dissolved in water, and finally reaches the tissues of the stem and the root.

b. Oxygen may enter the plant through the roots, soluble in water of the soil solution when it is absorbed by the root hairs, of imbibed by the cell walls.

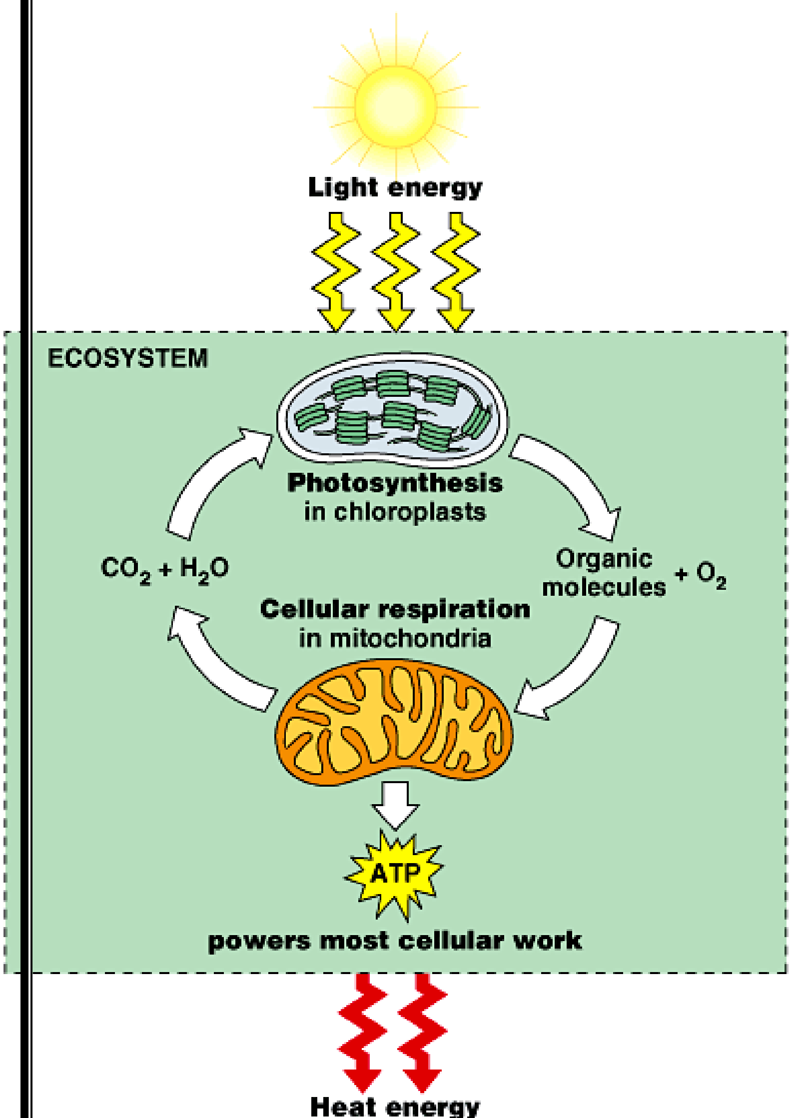
c. Through the stomata that spread on the surface of the stems of some plants (with green stems)

d. Through the lenticels or any cracks in the bark of woody stems.

N.B.: **Carbon dioxide resulting from respiration of the plant is expelled to the external environment by direct diffusion from plant cells that are directly exposed to the external environment. While in case of deep-seated cells, gaseous exchange occurs by mutual diffusion of CO2 in return to xylem and vessels or phloem tissue which passes CO2 in return to stomata, then to the external atmosphere.**

The relation between photosynthesis and respiration in plants:

The following figure represents the cycle of cellular respiration and photosynthesis. Study it and create your own comparison between the two processes.



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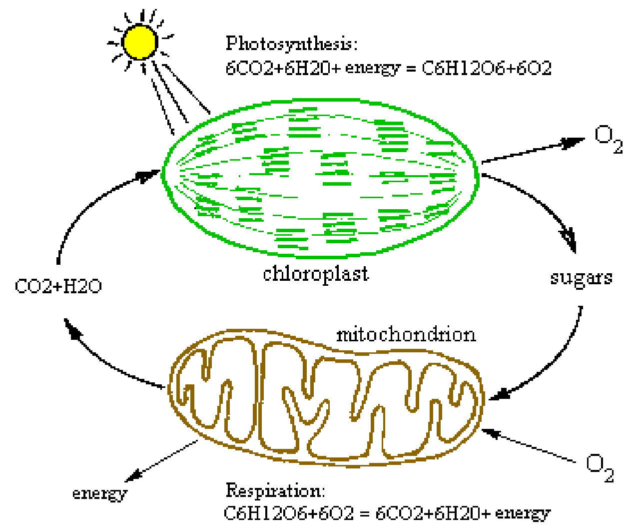


Figure 16 - With the photosynthesis, the solar energy is cumulated by the chloroplasts as sugar molecules. With the glycolysis and the respiration, made by mitochondria, the energy is liberated and supplied to the cell for its biochemical processes.

Experiments on Respiration

Experiment 1:
To illustrate the evolution of CO_2 gas during aerobic respiration:

A. In non-green parts of the plant (seeds):

1. Put some Potassium hydroxide solution (KOH) in a beaker. Insert some dry seeds (peas) in a glass retort, and dip the end of the retort stem in the Potassium hydroxide solution in the beaker. (apparatus no. 1)
2. Put some Sodium chloride solution (NaCl) in a beaker. Insert some soaked seeds in another retort, and dip the end of the retort stem in the Sodium chloride solution in that beaker. (apparatus no. 2)
3. Put another quantity of Potassium hydroxide solution (KOH) in a third beaker. Insert some soaked seeds in a third glass retort, and dip the stem of that retort in the Potassium hydroxide solution in that third beaker. (apparatus no. 3)
4. Leave the three retorts for some time.

Observation:

No change occurs in apparatus 1 and 2.
In case of retort 3: Potassium hydroxide solution rises up in the stem of the retort.

Interpretation:

In case of apparatus 1:

Dry seeds do not respire actively, therefore no change occurs under these conditions.

In case of apparatus 2:

Seeds soaked in water need to germinate and grow; therefore they must respire actively to obtain energy. They absorb Oxygen from the surrounding air, and they release an equal volume of CO2. So, no change is observed in the volume of the air inside the retort. This is because the released CO2 is not absorbed by Sodium chloride solution. So, the components of the air inside the retort have changed, but the total volume remains constant.

In case of apparatus 3:

The germinating seeds are actively respiring. CO2 gas is released in a volume equal to that of the absorbed Oxygen. The released CO2 will be absorbed by Potassium hydroxide solution. So, the solution rises up the stem of the retort.
This proves that CO2 gas is produced as a result of respiration in non-green parts of the plant (seeds).

By comparing the 3 cases, it is clear that:

1. Dry seeds do not respire actively. So, the volume and the components of air remain without change.
2. Germinating seeds respire actively and the volume of air remains constant during respiration because the released CO2 is equal in volume to the absorbed Oxygen.
3. When germinating seeds (which are non green parts of the plant) respire, they release Carbon dioxide gas.

B. Green parts of the plant:

1. Take a green potted plant, and place it on a glass plate together with a small beaker containing clear lime water. Invert a glass bell-jar over the two. Then cover the jar with a black piece of cloth.
2. Prepare a similar apparatus, with a pot empty of any cultivated plant.
3. Put some clear lime water in a small beaker, and leave it exposed to the atmospheric air.
4. Leave the 3 apparatus for some time.

Observation:

Lime water becomes turbid in (1) only.

Interpretation:

In (1), the green plant in the pot has respired and produced CO_2 gas, which causes the turbidity of lime water in the beaker. The bell-jar was covered with a black piece of cloth in order to keep light away from the plant and to stop the process of photosynthesis (which uses up CO_2 inside the bell-jar which has been released due to respiration).

In (2) and (3), the lime water shows no turbidity due to the small percentage of CO_2 whether in the air of the bell-jar or in the atmospheric air.

Experiment 2:
To illustrate the process of alcoholic fermentation:

1. Put a sugary solution (or molasses diluted with double of its volume with water) in a conical flask. Add a piece of Yeast and mix it thoroughly.
2. Close the flask with a stopper of rubber through which a delivery tube passes.
3. Dip the free end of the tube into a beaker containing lime water.
4. Leave the apparatus in a warm place for several hours.

Observation:

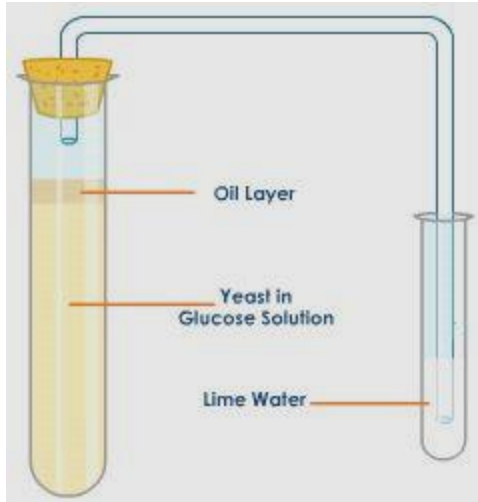
1. Gas bubbles are seen on the surface of the solution in the flask.
2. Lime water has become turbid.

Conclusion:

Turbidity of lime water is a proof that CO_2 gas has been evolved, as a result of the anaerobic respiration of yeast.

N.B.:

There is another kind of fermentation called acid fermentation carried out by several kinds of bacteria. It produces an acid instead of alcohol. Many milk products such as cheese, butter, and yoghurt are manufactured by this kind of fermentation.
Seeds of Angiosperms too, have the power to respire anaerobically, if they are kept under anaerobic conditions.



Revision VI
Respiration in Livings.

1. Give the scientific term that represents each of the following:

a. Extraction of energy from bonds of food molecules manufactured by plants or eaten by animals. (------------------------------)
b. Compounds that store energy extracted from food molecules. (---------------------)
c. The universal currency of energy in living cells. (-------------------------)
d. The 3 sub-units that form ATP molecule. (---)
e. The amount of energy released when a molecule of ATP is hydrolyzed. (--------------)
f. The substance commonly used by the majority of livings during the cellular respiration. (---------------------------)
g. The non organ part of the cytoplasm. (---------------------------)
h. The stage of cellular respiration that takes place in the cytosole. (-------------------)
i. The stages of cellular respiration that takes place inside the mitochondria. (---)
j. The electron carrier molecules. (----------------------------)
k. The break down of the glucose molecule. (---------------------------)
l. Co-enzymes which act as Hydrogen carriers. (------------------------------------)

m. The stage of respiration that take place in both aerobic and anaerobic respiration. (----------------------------------)
n. The products of Glycolysis. (---)
o. The products of Pyruvic acid oxidation. (---)
p. The 1st. compound formed during Krebs cycle. (--------------------------------------)
q. The 2- Carbon compound that joins Krebs cycle. (--------------------------------------)
r. The 1st. 3- Carbon compound formed during cellular respiration. (------------------)
s. The net energy released during Glycolysis in ATP molecules. (------------------------)
t. In its presence, Pyruvic acid molecules pass to the mitochondria. (--------------------)
u. The form to which proteins and fats are broken down to join Krebs cycle. (---------)
v. The 4- Carbon compound that reacts with acetyl co-A during Krebs cycle. (---------)
w. The 3 intermediate compounds that citric acid passes to form Oxaloacetic acid. (---)
x. No. of times of Krebs cycles per a Glucose molecule. (------------------------------)
y. The products of a Krebs cycle. (--)
z. No. of ATP molecules released during a Krebs cycle. (-------------------------)
a. No. of NADH molecules released during a Krebs cycle. (-------------------------)
b. No. of FADH2 molecules released during a Krebs cycle. (---------------------------)
c. No. of CO2 molecules evolved during a Krebs cycle. (------------------------------)
d. The last receptor of Hydrogen in the electron transport chain. (---------------------)

e. No. of ATP molecules formed from one molecule of NADH at the cytochromes. (---------------------------)
f. No. of ATP molecules formed from one molecule of FADH2 at the cytochromes. (---------------------------)
g. The total No. of ATP molecules formed from the complete oxidation of a Glucose molecule. (-------------------------------)
h. No. of ATP molecules released from a Glucose molecule in case of muscular fatigue. (-------------------------------)
i. Type of anaerobic respiration in case of muscle fibres and some bacteria. (---)
j. Type of anaerobic respiration in case of Yeast fungus, and some plant cells. (---)
k. The 3 reasons that make the nasal breathing preferable than the buccal one. (---)
l. The common passage for food and air. (-------------------------------------)
m. The voice box. (---------------------------------------)
n. The structures that line the trachea, and beat upwards. (-------------------------------)
o. The end of fine bronchioles. (------------------------------)
p. No. of alveoli per lung. (---------------------------)

q. The actual respiratory surface in the Human respiratory system. (---------------------)
r. The respiratory muscle. (---------------------------------)
s. Two groups of internal and external chest muscles that move the ribs. (---)
t. The percentage of lungs aeration to its capacity. (------------------------------)
u. The nervous centre that regulates the changes in the rate and depth of respiration, and heart beats. (------------------------------------)
v. Volume of water excreted daily as vapour from the Human body through lungs. (--------------------------------)
w. Volume of water lost daily from the Human body. (---------------------------------)
x. Openings that are present in the bark of woody stems. (--------------------------)
y. The type of fermentation that form an acid instead of an alcohol. (------------------)
z. The muscles that contract during inspiration. (---------------------------------)
a. The muscles that relax during expiration. (-------------------------------)
b. 5 passage ways through which O2 gas reaches the cells of a vascular plant. (--)
c. A group of plants that its seeds have the ability to respire anaerobically if they are kept under anaerobic conditions. (-----------------------)

2. Give reasons for:

a. The glucose molecule is considered as an excellent example to study the steps of breaking down the food molecules.
b. ATP molecules can be considered as the universal currency of energy in the cell.
c. Krebs cycle and electron transport take place both inside the mitochondria.
d. During the stages of cellular respiration co-enzyme that act as Hydrogen carriers are needed.
e. Krebs cycle happens twice per a Glucose molecule.
f. Krebs cycle needs no Oxygen.
g. The 1^{st}. compound formed during Krebs cycle is 6- Carbon compound.
h. Krebs cycle is also called Citric acid cycle.
i. Cytochromes are present at the inner membrane of the mitochondria.
j. Oxygen is considered the last receptor of Hydrogen in the electron transport chain.
k. Anaerobic respiration is called acidic fermentation in case of seeds of Angiosperms.
l. Anaerobic respiration is called alcoholic fermentation in case of Yeast fungus.
m. It's preferable for air to enter through the nose.
n. The trachea wall contains a series of cartilage ¾ rings.
o. The inner surface of the trachea is lined with cilia.

p. The thin alveolar walls are considered the actual respiratory surface in Man.
q. Atmospheric air is sucked inside the lungs in case of inspiration.
r. Air is forced out of lungs in case of expiration.
s. Aeration of lungs is a variable value.
t. At the end of expiration, a part of air is always left in the lungs.
u. The respiratory system in Man plays an important role in the excretion of water.
v. Its essential for the alveolar membranes to be moistened with water.

3. Draw a labeled diagram to represent:

a. The structure of a mitochondrion.
b. Glycolysis.
c. Krebs cycle.
d. The electron transport chain.
e. Calculation of ATP molecules released during the aerobic cellular respiration.
f. Anaerobic respiration.
g. The respiratory system in Man.
h. Mechanism of respiration in Man.

4. What do you know about:

a. Cellular respiration.
b. Electron transport chain.
c. Muscular Fatigue.
d. Alcoholic fermentation.
e. Adaptation features of the trachea to perform its function.
f. The actual respiratory surface in Man.
g. Aeration of the lungs.
h. The role of the respiratory system in Man in the excretion of water.
i. The relation between photosynthesis, and respiration in plants.

5. Describe the experiment, and draw the apparatus used:

a. Illustration of the alcoholic fermentation.
b. Release of CO2 during respiration of non-green parts in plants.
c. Release of CO2 during respiration of green parts in plants.

6. Compare between:

a. Inspiration and expiration.
b. Aerobic respiration, and anaerobic respiration.

c. Acidic fermentation and alcoholic fermentation.

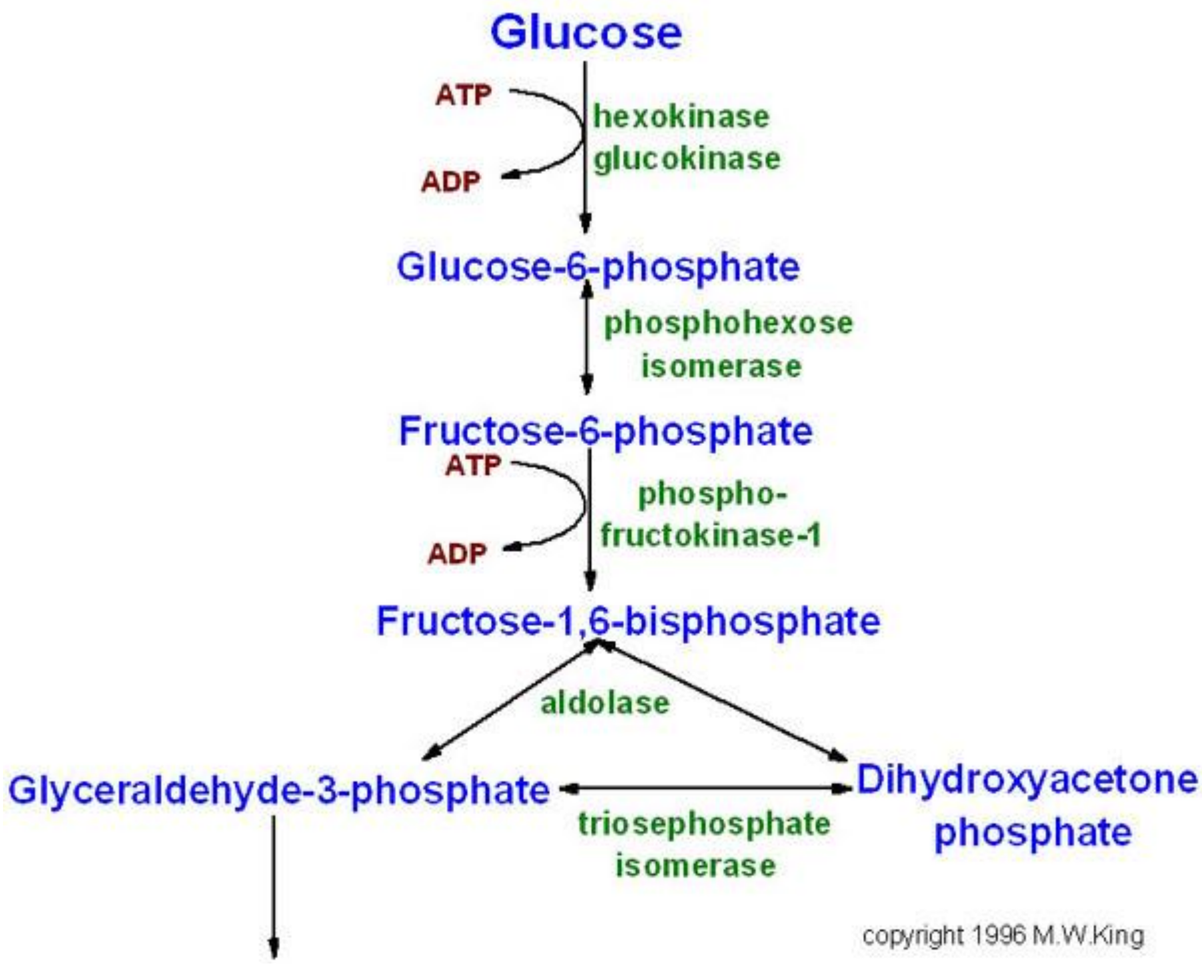
7. Write down the chemical equation that represents:

a. Cellular respiration.
b. Reduction of NAD+
c. Reduction of FAD.
d. Anaerobic respiration in case of Yeast fungus.
e. Anaerobic respiration in case of muscle fibres.
f. Formation of water molecules at the end of the electron transport chain.
g. Oxidation of Pyruvic acid molecules during the 1st. stage of Krebs cycle.
h. Joining of an acetyl co-A to Krebs cycle.

8. Calculate the total quantity of energy released during stages of the aerobic cellular respiration.

9. Describe in details the steps of Glycolysis, and its products.

10.What is the role played by ATP molecules in living cells, mention its structure, and describe how does this role be played?


Glucose
ATP
ADP
hexokinase
glucokinase
Glucose-6-phosphate
phosphohexose
isomerase
Fructose-6-phosphate
ATP
ADP
phospho-
fructokinase-1
Fructose-1,6-bisphosphate
aldolase
Glyceraldehyde-3-phosphate
Dihydroxyacetone
phosphate
triosephosphate
isomerase
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